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[54] **ELECTRONICALLY ERASABLE-PROGRAMMABLE MEMORY CELL HAVING BURIED BIT LINE**

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[51] Int. Cl.^{6} G11C 7/00; H01L 29/788
[52] U.S. Cl. **365/185.16**; 257/315; 257/316
[58] Field of Search 365/185; 257/365, 257/390, 314–320

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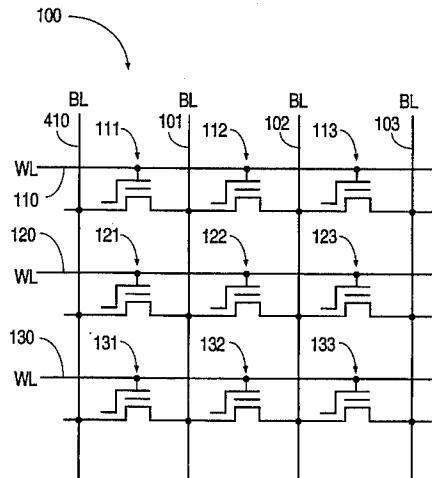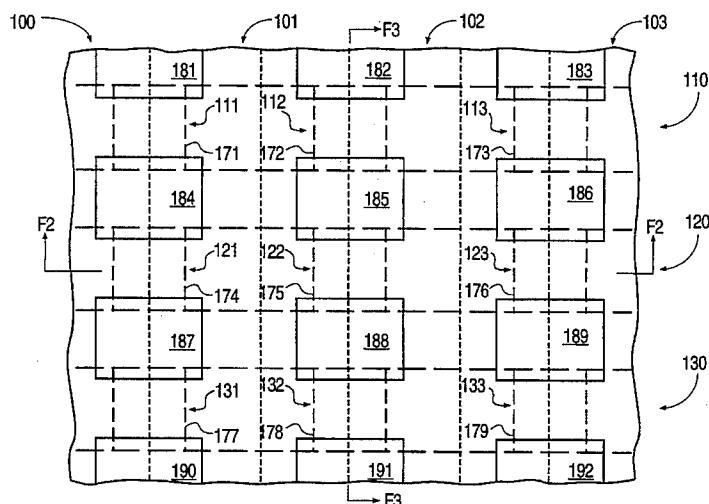*Primary Examiner*—David C. Nelms
Assistant Examiner—Son Mai
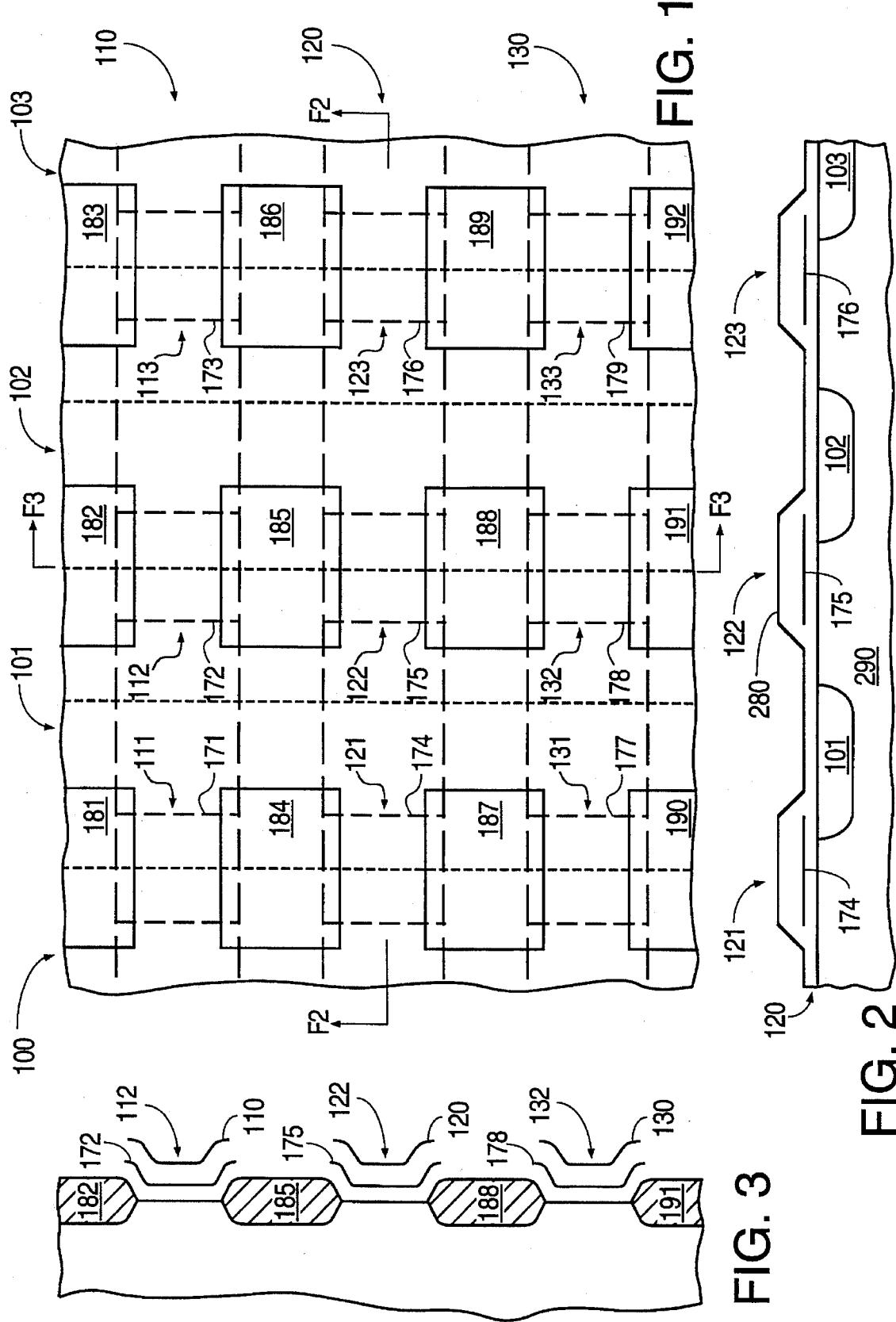*Attorney, Agent, or Firm*—Skjerven, Morrill, MacPherson, Franklin & Friel; David H. Carroll

[57] **ABSTRACT**

A memory cell (510) suitable for an array of memory cells (100) has a source that is part of a buried bit line and a drain that is part of an adjacent buried bit line. The memory cell also includes a split gate arrangement (580) in which the gate is integral with the word line (120), with a part of the gate being the control gate of an EEPROM transistor which erases and programs on the principle of Fowler-Nordheim tunneling (560, 570), and another part of the gate being the control gate of a series select transistor. The memory cell is erased by placing a voltage on the word line which is positive relative to the bit line and the substrate and of sufficient magnitude to cause tunneling. The memory cell is programmed by placing a negative voltage on the word line and a voltage corresponding to the logical value on the bit line. The bit line voltage is sufficient to cause tunneling for one logical value, and insufficient to cause tunneling for the other logical value. The memory cell is read by placing a sense voltage across the bit lines forming its source and drain, and a read voltage on the control gate. Other bit lines are left floating.

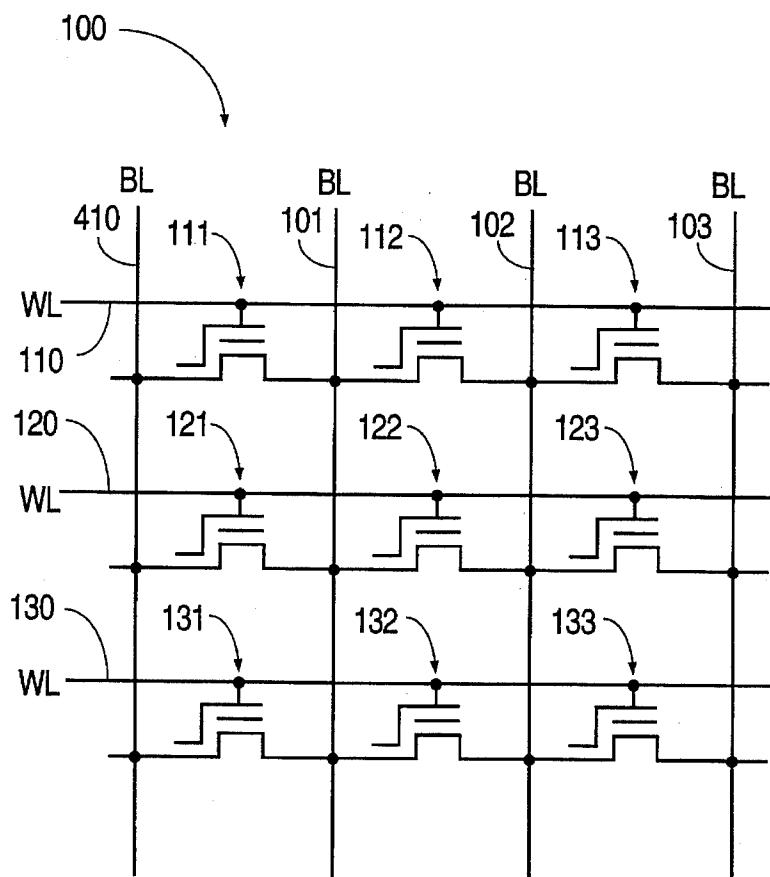**28 Claims, 5 Drawing Sheets**

FIG. 1
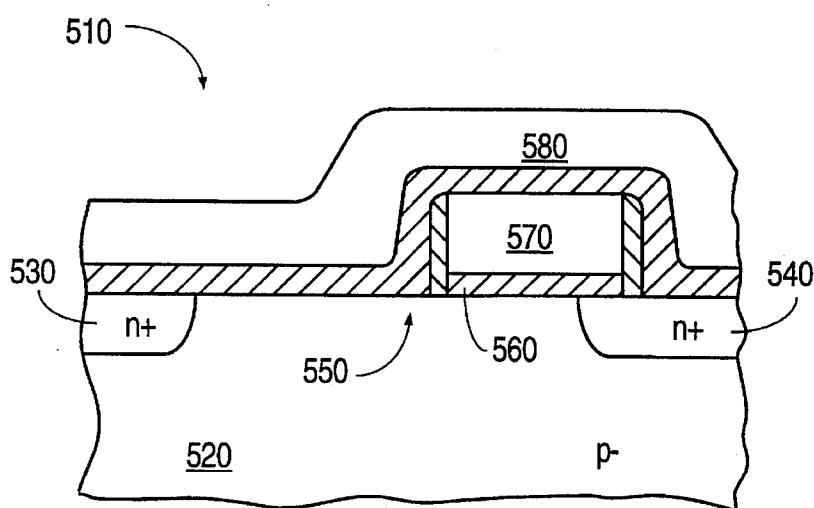
FIG. 2

FIG. 3

100

BL   BL   BL   BL
410   111   101   112   102   113   103

WL
110

120
WL

130
WL

FIG. 4

510

580

570

530   540
n+   550   560   n+

520   p-

FIG. 5

611   612   613

181   182   183

184   185   186

187   188   189

190   191   192

FIG. 6

701

702

703

611

612

613

FIG. 7

810

820

830
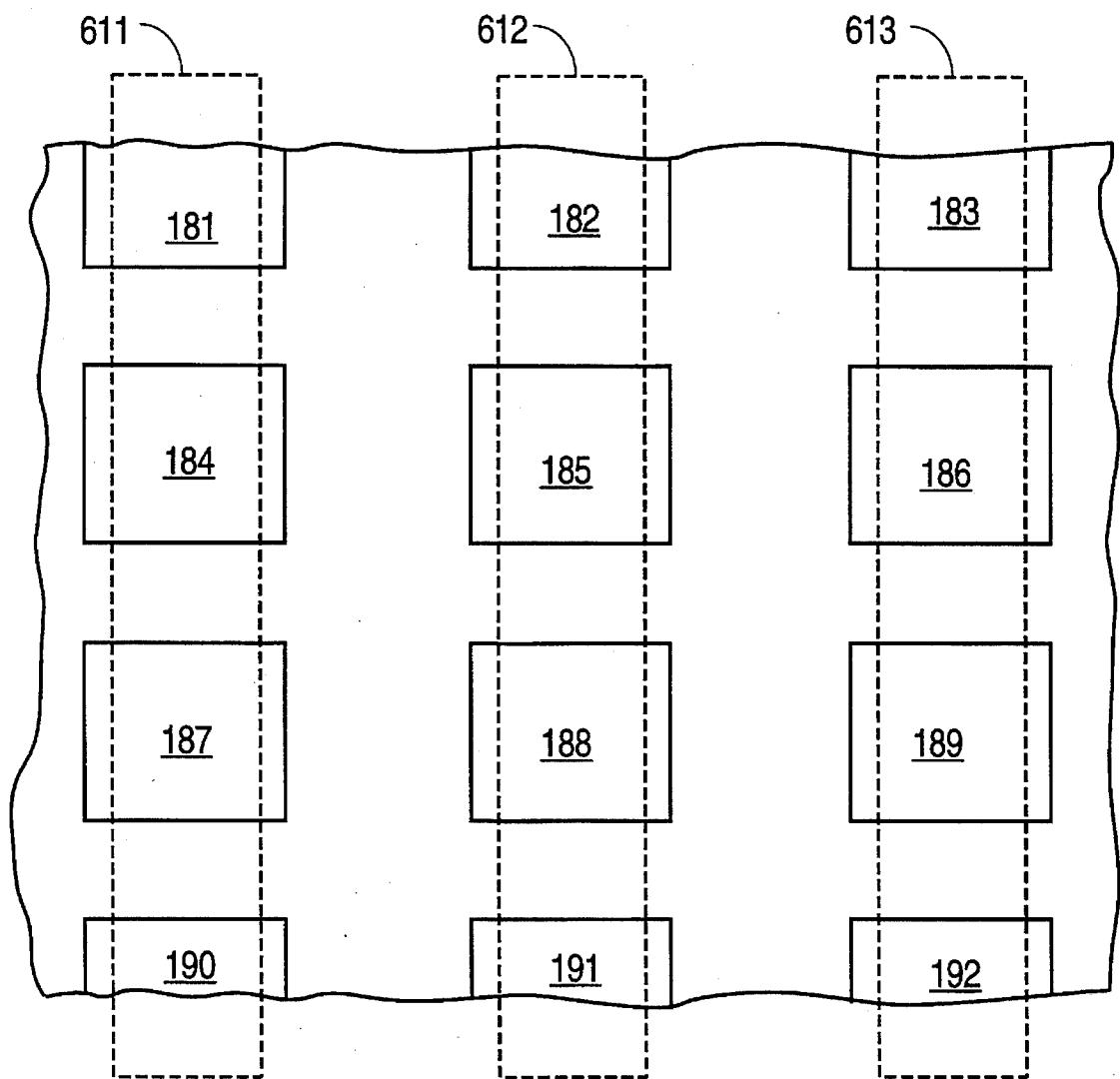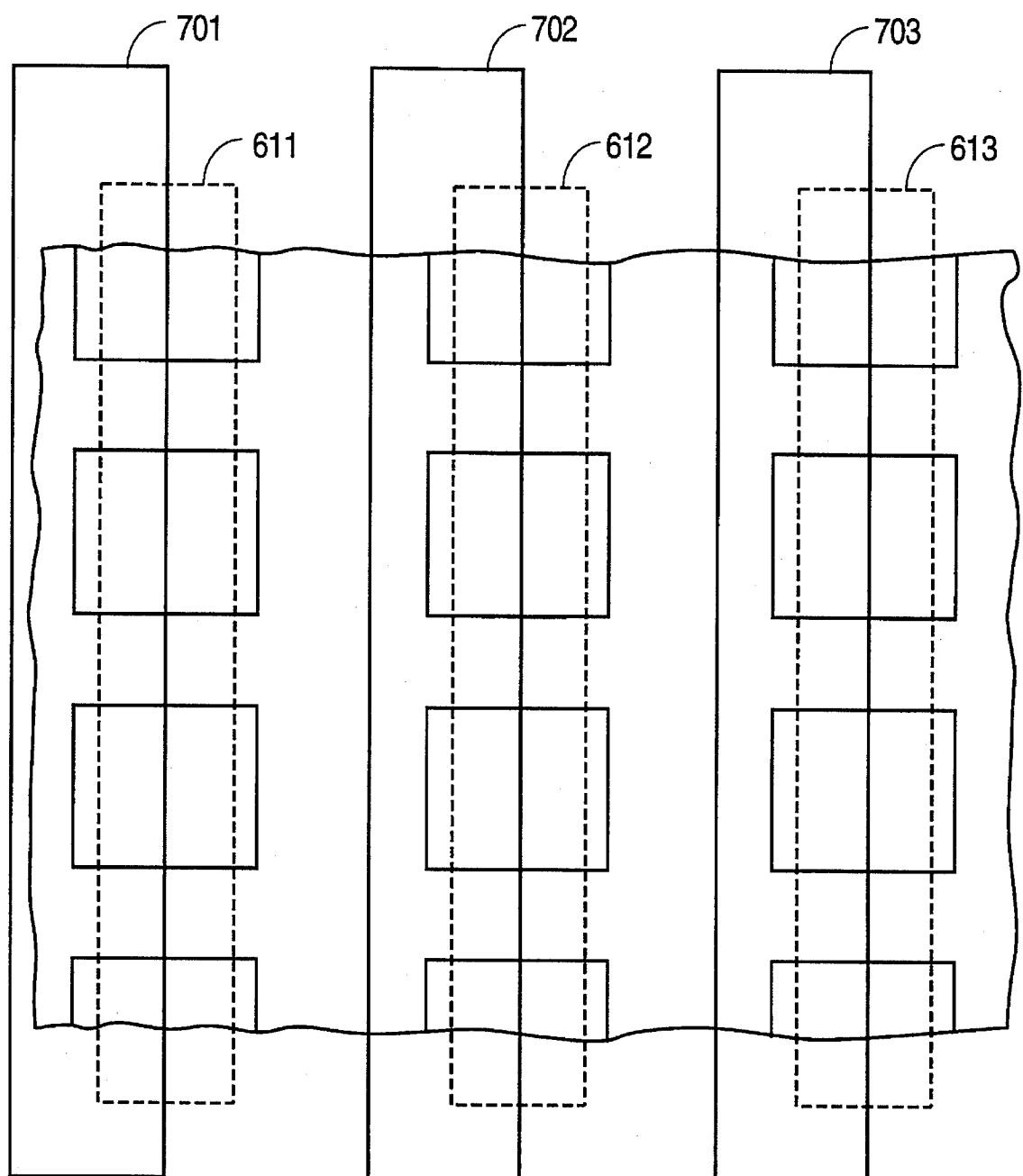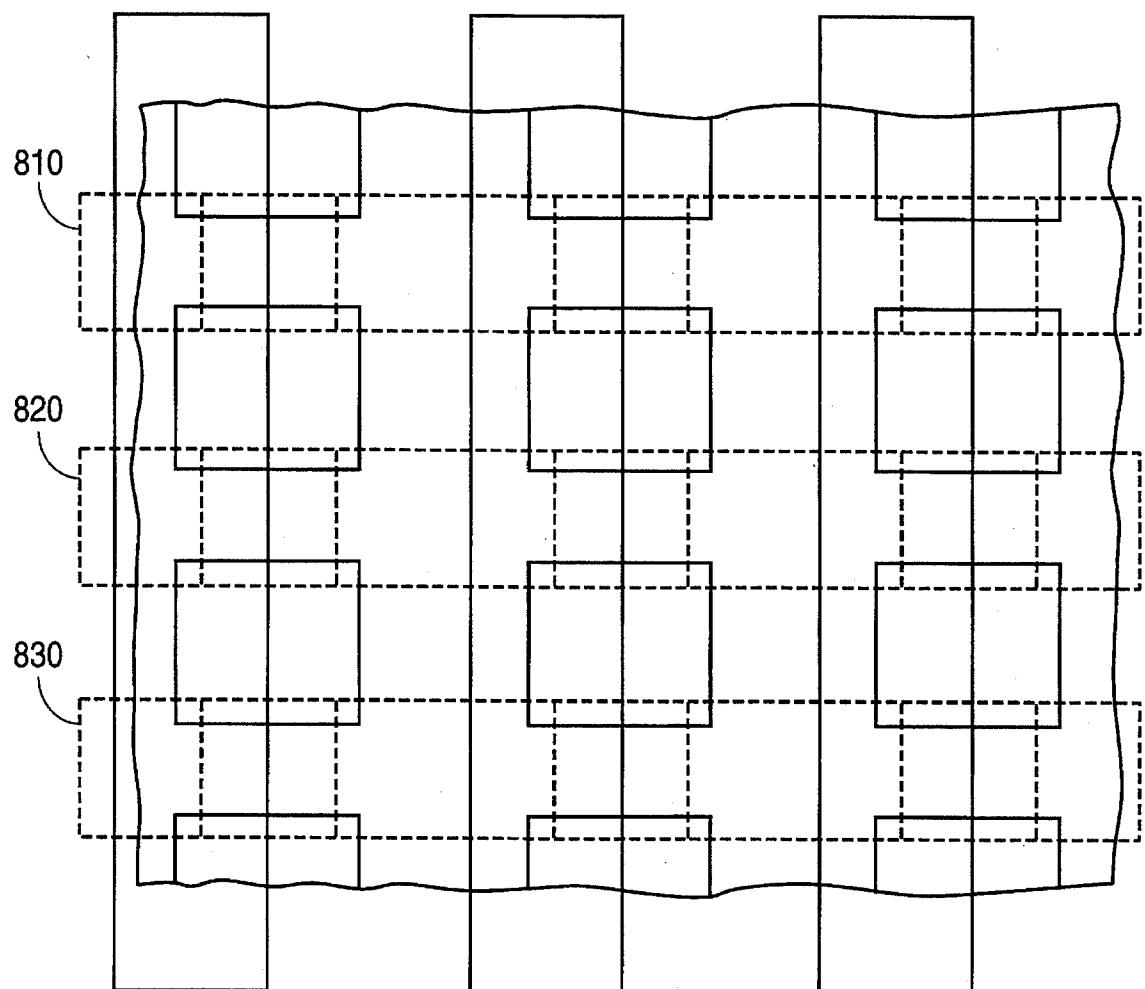
FIG. 8

ELECTRONICALLY
ERASABLE-PROGRAMMABLE MEMORY
CELL HAVING BURIED BIT LINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to memory cell arrays, and more particularly to arrays of electrically erasable and programmable memory cells which are based on Fowler-Nordheim tunneling.

2. Background of the Invention

One of the important factors for a successful memory design is minimization of the size of the memory array. Flash EEPROM (electrically erasable and programmable read-only memory) technology provides a cell size similar to EPROM (erasable programmable read-only memory) technology as well as electrical erasability.

Because EEPROM devices are electrically erasable, they do not require the expensive ceramic-quartz window packages used for conventional EPROM devices. On the other hand, electrical erasing can leave the floating gate positively charged, converting the memory transistor into a depletion mode transistor.

Techniques have been developed to avoid positively charging the floating gate during erasure. One technique known as adaptive erasure uses an algorithm to control the amount of charge applied to the memory transistor during erasure. Unfortunately, adaptive erasure has the disadvantage of being relatively slow and difficult to implement in large memory arrays. Another approach uses a cell that comprises a floating gate memory transistor similar to an EPROM cell connected in series with a simple enhancement transistor controlled by the word line. This cell, which is more fully described in Samachisa et al, "A 128K Flash EEPROM Using Double-Polysilicon Technology," IEEE J. Solid-State Circuits, Vol. SC-22, No. 5, October 1987, pp. 676–683, avoids leakage current during programming and reading because of the action of the series enhancement transistor. The EPROM device in the cell is erased using Fowler-Nordheim tunneling and programmed using hot-electron injection, which is typical for EPROM devices. Unfortunately, the presence of the series enhancement transistor increases the size of the Flash EEPROM cell of Samachisa et al.

Given the considerable commercial importance placed on small memory size, further miniaturization in cell and array size is desirable.

SUMMARY OF THE INVENTION

An advantage of one or more embodiments of the present invention is the achievement of a small EEPROM memory cell size. A further advantage of one or more embodiments of the present invention is the achievement of EEPROM operation without concern for the memory transistor of the cell entering into depletion mode.

These and other advantages are achieved in the present invention, which in one embodiment is a memory cell having first and second electrically conductive lines of a second conductivity type disposed in a semiconductor body of a first conductivity type. The first line includes a data carrying capability. A first section of the memory cell comprises a drain formed at least in part by the first line, a floating gate, a first control gate, and a first channel region

adjacent the drain and within control of the floating gate and the first control gate. A second section of the memory cell comprises a source formed at least in part by the second line, a second control gate, and a second channel region adjacent the source and within control of the second control gate. The first and second control gates are integral and the first and second channel regions are integral.

In another embodiment of the present invention, a memory array comprises a plurality of data carrying lines, a plurality of word lines, and a plurality of memory cells. Each of the memory cells comprises a select transistor coupled to an EEPROM transistor. The EEPROM transistor has a floating gate and also a drain coupled to an associated one of the data carrying lines. The select transistor has a source coupled to a data carrying line adjacent the associated data carrying line. The gates of the select transistor and the EEPROM transistor are commonly coupled to an associated one of the word lines.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a composite layout diagram of an array of EEPROM memory cells.

FIGS. 2 and 3 are cross-sectional diagrams of sections F2—F2 and F3—F3 through a memory array based on the layout of FIG. 1.

FIG. 4 is an equivalent transistor-level schematic diagram of the memory array of FIG. 1.

FIG. 5 is a cross-sectional diagram of a type of EEPROM memory cell based on Fowler-Nordheim tunneling and useful in the memory array of FIG. 1.

FIGS. 6–8 are composite layout diagrams representing the memory array of FIG. 1 in various stages of fabrication.

DETAILED DESCRIPTION OF THE
PREFERRED EMBODIMENT

The memory array 100 shown in FIG. 1 is a remarkably compact array structure. The portion illustrated represents only a part of a larger grouping of cells, which may serve as the memory array or as a subarray for a larger memory array organized in accordance with other memory design principles. In the interest of clarity, such well known memory elements as sense amplifiers, latches, pull-up circuits, word line amplifiers, and word and bit line decoders are omitted from the figures showing the memory array 100.

The memory array 100 includes identical Flash EEPROM memory cells 111–113, 121–123, and 131–133, which are of the type shown in FIG. 5 as cell 510. The cell 510 is an n-channel Flash EEPROM cell which includes an n-type source 530 and an n-type drain 540 disposed in a p-type semiconductor substrate region 520. Erasure and programming are based on Fowler-Nordheim tunneling through a tunnel oxide 560. A channel region 550 is defined in the substrate region 520 between the source 530 and drain 540. Minority carrier conduction in the part of the channel region 550 adjacent the drain 540 is controlled by the combined effect of a floating gate 570 and a control gate 580, in a manner well known in the art. Minority carrier conduction in the part of the channel region 550 adjacent the source 530 is controlled by the control gate 580, in the manner of a select transistor. This arrangement, called a "split gate" arrangement, is particularly advantageous because it includes an integrated transistor to control the electrical current in the channel region 550 which is partially controlled by a floating gate. Therefore if the channel region

under the floating gate **570** is in depletion-mode due to over-erase, the split gate arrangement still turns off the leakage current path between the drain **540** and the source **530**.

While the small size of the flash EEPROM cell **510** of FIG. **5** renders cell **510** particularly well suited for inclusion in the memory array **100** shown in FIG. **1**, other types of Flash EEPROM cells based on Fowler-Nordheim tunneling may be used as well. For example, the EEPROM transistor described in U.S. application Ser. No. 07/645,507, filed Jan. 24, 1991 (entitled "Single Transistor EEPROM Architecture" and naming Nagesh Challa as inventor), and in U.S. application Ser. No. 07/973,809, filed Nov. 9, 1992 (entitled "Single Transistor EEPROM Architecture" and naming Nagesh Challa as inventor), which is hereby incorporated herein by reference in its entirety may be paired with a separate conventional n-channel MOSFET select transistor, although such a combination would not be as compact as the cell **510**.

Cells **111–113**, **121–123**, and **131–133** are incorporated into the memory array **100** in a substantially identical manner. The incorporation of cell **122** is representative. With reference to FIGS. **1–4** (dielectric structures are omitted from FIGS. **2** and **3** for clarity), note that the floating gate **175** (other floating gates in the memory array **100** are indicated at **171–174** and **176–179**) is uniquely associated with cell **122**, while the control gate **280** is part of the word

560 to place the cell in a low threshold voltage state V_{t1}, and which for the other logical state of the data does not cause electrons to tunnel from the floating gate **570** to the drain **540** so that the high voltage threshold state V_{th} is maintained. An illustrative programming voltage is fifteen volts, although it will be appreciated that the design of cells having other values of programming voltage is within the ability of one of ordinary skill in the art. The cell **510** is read by placing a sufficient sense voltage difference across the source **530** and the drain **540**, and a read voltage V_r on the control gate **580**. The value of read voltage V_r is sufficient to induce a channel in the portion of the channel region **550** adjacent the source **530**. The value of read voltage V_r is sufficient to induce a channel in the portion of the channel region **550** adjacent the drain **540** if the threshold voltage of the cell **510** is V_{t1}, and insufficient to induce a channel in the portion of the channel region **550** adjacent the drain **540** if the threshold voltage of the cell **510** is V_{th}. An illustrative sense voltage difference is two volts and an illustrative read voltage is three volts, although it will be appreciated that the design of cells having other values of sense and read voltages is within the ability of one of ordinary skill in the art.

Illustrative voltages for the various modes of operation of the memory array **100** are summarized in Table 1, with reference to cells **121**, **122** and **123**.

TABLE 1

MODE		WL 110 130	WL 120	BL 410	BL 101	BL 102	BL 103	SUB
ERASE	Make V_t of cells 121, 122 and 123 high	15	15	–3	–3	–3	–3	–3
PROGRAM	Make V_t of cell 122 low; do not disturb V_t of other cells	0	–11	0	0	4	0	0
READ	Source/drain can be assigned either way							
	Cell 122 (S/D: 101/102)	0	3	F	0	2	F	0
	Cell 122 (S/D: 102/101)	0	3	F	2	0	F	0

line conductor **120**. Note also that the source of the cell **122** is part of a buried bit line **101**, while the drain of the cell **122** is part of a buried bit line **102**. The use of each buried bit line as a source for one cell and a drain for an adjacent cell helps to achieve a small cell and array size.

Erasure and programming of the cell **510** is in accordance with Fowler-Nordheim tunneling through a portion of a dielectric **560** between the drain **540** and the floating gate **570**. The cell **510** is erased, or placed in a high voltage threshold state V_{th}, by applying a potential difference across the control gate **580** and either the drain **540**, the channel region **550**, or both, so that electrons tunnel through the dielectric **560** to reside in the floating gate **570**. Applying a voltage to the channel region **550** is known as "backgating" or "backbiasing" the MOSFET transistors in the cell **550**. An illustrative erase voltage is eighteen volts, although it will be appreciated that the design of cells having other values of erase voltage is within the ability of one of ordinary skill in the art. The cell **510** is programmed by applying a particular voltage to the control gate **580** and by applying to the drain **540** a voltage relative to the control gate voltage which for one logical state of the data causes electrons to tunnel from the floating gate **570** to the drain **540** through the dielectric

Illustrative, the memory array **100** is erased by placing a voltage on the word lines **110**, **120** and **130** that is sufficiently positive relative to the voltage on the bit lines **410**, **101**, **102** and **103** so that tunneling occurs into the floating gate of each of the cells **111– 113**, **121–123** and **131–133**, thereby placing the cells in the V_{th} state. For example, the entire memory array **100** is erased by applying fifteen volts to word lines **110**, **120** and **130** and minus three volts to the bit lines **410**, **101**, **102** and **103** and backbias. Focussing on cell **122** as illustrative of the other cells in the memory array **100** during erasure, the substrate **290** (which may be a p-well, for example) and the drain (bit line **102**) of cell **122** are at minus three volts while the control gate **280** is at fifteen volts. Electrons tunnel from the source and channel regions of the cell **122** into the floating gate **175**, causing the cell **122** to acquire a high threshold voltage V_{th}.

Alternatively, erasing may be done on a word-by-word basis by placing the sufficiently positive voltage on one particular word line while floating the other word lines, or while maintaining the voltage on the other word lines at a suitable voltage, illustratively about the voltage on the bit lines, so that erasure does not occur.

Illustratively, a single cell of the memory array **100** is programmed by placing a voltage on its associated word line that is sufficiently negative relative to the voltage on the associated bit line so that tunneling occurs from the floating gate, thereby placing the cell in the V_{t1} state. To program cell **122**, for example, minus eleven volts is placed on the word line **120** and plus four volts is placed on the bit line **102** to provide the illustrative tunneling voltage of fifteen volts. The other word lines **110** and **130** and the other bit lines **101** and **103** are held at zero so that the voltage across the control gates and drains of the other cells in the memory array is insufficient to cause tunneling. The binary values stored in those cells is unaffected. Specifically, the voltage across the control gates and drains is zero for cells **111**, **113**, **131** and **133**, four volts for cells **112** and **132**, and minus eleven volts for cells **121** and **123**, all insufficient to appreciably change the Vt of those memory cells.

Illustratively, a single cell of the memory array **100** is read by precharging one of the bit lines associated with the cell while placing the other associated bit line at reference potential and applying a read voltage on its associated word line. Unassociated bit lines are left floating. Note that advantageously either bit line may serve as source while the other serves as drain. Cell **122** is read, for example, by precharging bit line **102** to two volts and applying zero volts to bit line **101** and three volts to the word line **120**. If cell **122** is in a V_{th} state, the cell remains nonconductive and the bit line **102** remains charged, indicating a logical zero, for example. If cell **122** is in a V_{t1} state, the cell becomes conductive and the bit line **102** discharges, indicating a logical one, for example.

Because the word line **120** is at V_r, the select transistors in the memory cells **121** and **123** are on and the cells themselves could be conductive depending on the value of their V_r. Since bit line **410** associated with cell **121** and bit line **103** associated with cell **123** are floating, neither memory cells **121** nor **123** actually conducts, and the reading of memory cell **122** is unaffected.

The word lines **110** and **130** are at reference potential. Hence, the select transistors in the memory cells **111**–**113** and **131**–**133** are off and prevent the memory cells **111**–**113** and **131**–**133** from being read.

The memory array **100** may be fabricated in any suitable field effect transistor technology by any suitable process. Fabrication of the memory array **100** in accordance with, for example, an illustrative CMOS process is shown generally in FIGS. **6**–**9**, although it will be understood that NMOS and other CMOS processes may be used as well. It will also be understood that some of the steps described are not used in the formation of the memory array **100**, but are useful in forming circuits that may be formed outside of the region shown in FIG. **1**.

The starting material is a p-type substrate **290** doped to a conductivity of, for example, 25 ohm-cm. The first mask, an n-well mask, is applied after an initial oxidation and nitride deposition, followed by a nitride etch, an n-well implant, an n-well oxidation, a nitride strip, a p-well implant, an n-well drive-in, and an oxide removal. The second mask, an active area mask, is applied after a base oxidation and nitride deposition, followed by a nitride etch and a blanket n-field implant. The third mask, a p-field mask, is then applied, followed by an p-field implant, resist removal, and a field oxidation.

In the field oxidation step, a matrix of field oxide islands **181**–**192** is formed in a p-region of the substrate **290**, as shown in FIG. **6**. Each of the field oxide islands **181**–**192** is

6500 Å thick, and is a rectangle measuring about 1.4 microns from left to right, and about 1.2 microns from top to bottom. The p-type active area between adjacent islands **181**–**192** measured from left to right is about 1.2 microns, while the p-type active area between adjacent islands **181**–**192** measured from top to bottom is about 0.6 microns.

Following field oxidation, a nitride strip is done, followed by a pre-gate oxidation to form a 300 Å oxide. The fourth mask, a cell mask, is then applied, followed by a suitable array V_t implant, a sacrificial oxide removal, and an array gate oxidation. Illustratively, gate oxide is formed to a thickness of 100 Å.

The fifth mask, a first poly mask, is applied after a layer of polysilicon is deposited to a thickness of 1500 Å and suitably implanted with a dopant such as, for example, phosphorus at a dose of 5×10^{14} and an energy of 30 Kev. After the first poly mask is applied, the first polysilicon layer is etched to form numerous polysilicon features, including polysilicon strips **611**–**613** as shown in FIG. **6**. Polysilicon strips **611**–**613** run from top to bottom over, respectively, islands **181**, **184**, **187**, and **190**; islands **182**, **185**, **188**, and **191**; and islands **183**, **186**, **189** and **192**. A resist removal step follows.

The sixth mask, a buried bit line implant mask, is applied next. As shown in FIG. **7**, the bit line implant mask includes protective strips **701**, **702** and **703**, and an n+ implant is made through the windows between, for example, the strips **611** and **702** and the strips **612** and **703**, to form the buried bit lines **101** and **102**. The implant is any suitable n-type dopant or combination implanted at any suitable dose and energy. For example, a suitable dopant combination is arsenic implanted at a dose of 2×10^{15} and an energy of 80 Kev, followed by phosphorus implanted at a dose of 2×10^{14} and an energy of 80 Kev. This combined implant results in an n-type sheet resistance of from about 25 to 35 ohms/square. The resist is removed, followed by a sequence of steps to form a dielectric layer such as, for example, an oxide-nitride-oxide ("ONO") sandwich. Illustratively, the first layer is a 120 Å oxide formed by a polysilicon oxidation, the next layer is a 120 Å nitride layer formed by nitride deposition, and the next layer is a 50 Å oxide formed by oxidation of the nitride layer, resulting in a 200 Å oxide equivalent dielectric.

The seventh mask is an V_t implant mask, followed by a blanket V_t adjust implant to achieve the native V_r.

An eighth mask, an array protect mask, is then applied. The array protect mask protects the ONO dielectric, which is an interpoly dielectric, in the memory array area as areas (not shown) outside of the memory array area are etched to remove the ONO dielectric in preparation for gate dielectric formation. Next, a gate oxide is grown by any suitable process in areas outside of the memory array area to form a gate dielectric about 250 Å thick.

A ninth mask, a second poly mask, is applied after a second poly deposition and a tungsten silicide deposition. The second poly is deposited to any suitable thickness such as, for example, a thickness in the range 1000 Å–2000 Å. The tungsten silicide is deposited to any suitable thickness such as, for example, a thickness in the range of 1000 Å–2000 Å. In the memory array **100** area, the second poly mask includes protective strips **810**, **820** and **830**. The next step is a second poly etch, which results in the word lines **110**, **120** and **130** being formed under the protective strips **810**, **820** and **830**. The second poly etch is followed by a first poly etch to remove exposed regions of the first poly strips **611**–**613**, resulting in the self-aligned polysilicon rectangles

171–179 that form the respective floating gates of the cells **111–113, 121–123,** and **131– 133.** The next step is a second poly oxidation step.

The subsequent steps are any suitable steps for completing the devices, including passivation, forming contact vias to the various device terminals, and metalization. Steps of this nature, commonly referred to as the CMOS back end, are well known in the art.

The description of the invention set forth herein is illustrative, and does not necessarily limit the scope of the invention as set forth in one or more of the following claims. Many variations and modifications may be made based on the description set forth herein, without departing from the scope and spirit of the invention. For example, the operating voltages for the memory array **100** set forth herein are illustrative, and other operating voltages may be used depending on the particulars of the devices and processes used to form them. Moreover, terms such as word line and bit line are used in their broad, nonlimiting sense. For example, as applied to some types of memories, "bit line" means a global data carrying line, while as applied to other types of memories, "bit line" means a local data carrying line.

What is claimed is:

1. A memory cell that is electrically erasable and programmable, comprising:
   a semiconductor body of a first conductivity type having a generally planar surface region;
   a first electrically conductive line of a second conductivity type extending into the semiconductor body from the generally planar surface region, the first line including a data carrying capability;
   a second electrically conductive line of the second conductivity type extending into the semiconductor body from the generally planar surface region and spaced apart from the first line;
   a first section comprising a drain formed at least in part by the first line, a first channel region disposed adjacent the drain in the semiconductor body, a floating gate overlapping the first channel region and further overlapping at least a portion of the drain and insulated therefrom by a dielectric for supporting Fowler-Nordheim tunneling, and a first control gate overlapping at least a portion of the floating gate over the first channel region, the first channel region being within control of the floating gate and the first control gate; and
   a second section comprising a source formed at least in part by the second line, a second channel region disposed adjacent the source in the semiconductor body, and a second control gate, overlapping the second channel region, the second channel region being within control of the second control gate, the first and second control gates being integral, and the first and second channel regions being integral.

2. A memory cell as in claim **1** wherein the substrate is a p-type region and the first line is an n-type region.

3. A memory cell as in claim **2** wherein the first line is a heavily doped n-type region.

4. A memory cell as in claim **1** wherein the second line includes a data carrying capability.

5. A memory cell as in claim **4** wherein the substrate is a p-type region, the first line is an n-type region, and the second line is an n-type region.

6. A memory cell as in claim **5** wherein the first and second lines are heavily doped n-type regions.

7. A memory cell as in claim **1** wherein the first and second control gates are part of a word line, and wherein the first line is part of a bit line.

8. A memory cell that is electrically erasable and programmable, comprising:
   a p-type semiconductor body;
   a first n-type bit line extending into the semiconductor body from a first surface strip of the semiconductor body;
   a second n-type bit line extending into the semiconductor body from a second surface strip of the semiconductor body, the second bit line being parallel to the first bit line;
   a control gate comprising an electrically conductive polysilicon strip disposed over the semiconductor body and transverse to the first and second bit line for controlling a channel region disposed in the semiconductor body under a third surface strip and between the first and second bit lines, the first, second and third surface strips being coplanar and a portion of the first bit line being adjacent the channel region for functioning as a drain, and a portion of the second bit line being adjacent the channel region for functioning as a source; and
   a floating gate comprising a polysilicon element disposed between a portion of the polysilicon strip and a portion of the semiconductor body comprising a portion of the drain and a portion of the channel region adjacent the drain, the floating gate polysilicon element being separated from the drain by a dielectric for supporting Fowler-Nordheim tunneling.

9. A memory element as in claim **8** wherein the polysilicon element is separated from the semiconductor body portion by a tunnel dielectric.

10. An electrically erasable and programmable memory array comprising:
   a semiconductor body having a generally planar major surface;
   a plurality of buried data carrying lines extending into the semiconductor body from the major surface thereof;
   a plurality of word lines;
   a plurality of memory cells, each of the memory cells being associated with one of the word lines and one of the data carrying lines and comprising a select transistor coupled to an electrically erasable programmable read-only memory ("EEPROM") transistor, the EEPROM transistor having a control gate and a floating gate and further having a drain insulated from the floating gate by a tunnel dielectric and coupled to the associated one of the data carrying lines, the select transistor having a control gate and further having a source coupled to one of the data carrying lines adjacent the associated data carrying line, the control gates of the select transistor and the EEPROM transistor being commonly coupled to the associated one of the word lines.

11. An electrically erasable and programmable memory array comprising:
   a semiconductor body having a generally planar major surface;
   a plurality of substantially parallel data carrying lines extending into the semiconductor body from the major surface thereof;
   a plurality of substantially parallel word lines disposed over the semiconductor body, the word lines being transverse to the data carrying lines; and
   a plurality of memory cells, each of the memory cells being associated with one of the word lines and one of the data carrying lines and comprising a select transis-

tor having a control gate for controlling a first channel, integrated with an electrically erasable programmable read-only memory ("EEPROM") transistor having a control gate for controlling a second channel and a floating gate, the EEPROM transistor further having a drain comprising a pan of the associated one of the data carrying lines and insulated from the floating gate by a tunnel dielectric, the select transistor having a source comprising a part of one of the data carrying lines adjacent the associated data carrying line, the control gates of the select transistor and the EEPROM transistor being integral with the associated word line, and the first and second channels of the select transistor and the EEPROM transistor respectively being integral.

12. An electrically erasable and programmable memory cell disposed in a generally planar surface region of a semiconductor substrate, comprising:

a first doped region extending into the substrate from the surface region, the first doped region providing a bit line connectable to other cells in a column;

a second doped region extending into the substrate from the surface region and separated from the first doped region by a channel region;

a floating gate disposed over a portion of the channel region and insulated therefrom by a dielectrics and further disposed over a portion of the first doped region and insulated therefrom by a tunnel dielectric;

a control gate disposed over the floating gate and over the channel region, and insulated therefrom by a dielectric.

13. A memory cell as in claim 12 wherein the first and second doped regions are n-type and the substrate is p-type.

14. A memory cell as in claim 13 wherein:

the floating gate and the word line comprise polysilicon; and

the tunnel dielectric comprises silicon dioxide.

15. An array of electrically erasable and programmable memory cells disposed in a region of a semiconductor substrate, comprising:

a first doped region extending into the substrate from a first generally planar strip-like surface region of the substrate, the first doped region providing a bit line; and

a second doped region extending into the substrate from a second generally planar strip-like surface region of the substrate, the second doped region being parallel to the first doped region;

wherein each of the memory cells comprises:

a channel region disposed between the first doped region and the second doped region and extending from a third generally planar surface region of the substrate, the first, second and third surface regions being coplanar;

a floating gate disposed over a portion of the channel region and insulated therefrom by a dielectric, and further disposed over a portion of the first dope region and insulated therefrom by a tunnel dielectric; and

a control gate disposed over the floating gate and over the channel region, and insulated therefrom by a dielectric.

16. A memory cell as in claim 15 wherein the first and second doped regions are n-type and the substrate is p-type.

17. A memory cell as in claim 15 wherein:

the floating gate and the word line comprise polysilicon; and

the tunnel dielectric comprises silicon dioxide.

18. A memory cell as in claim 7 wherein the first and second channel regions comprise a dopant having a substantially uniform distribution in a direction parallel to the substantially planar surface.

19. A memory cell as in claim 8 wherein the control gate is a region of a word line.

20. A memory cell as in claim 19 wherein the channel region comprises a dopant having a substantially uniform distribution in a direction parallel to the third surface strip.

21. A memory cell as in claim 10 wherein the control gates of the select transistor and the EEPROM transistor comprise portions of the associated one of the word lines.

22. A memory cell as in claim 21 wherein the select and EEPROM transistors comprise an integrated channel with a dopant having a substantially uniform distribution in a direction parallel to the generally planar major surface.

23. A memory cell as in claim 11 wherein the control gates of the select transistor and the EEPROM transistor comprise portions of the associated word line.

24. A memory cell as in claim 23 wherein the first and second channels comprise a dopant having a substantially uniform distribution in a direction parallel to the generally planar major surface.

25. A memory cell as in claim 12 wherein the control gate comprises a portion of a word line.

26. A memory cell as in claim 25 wherein the channel region comprises a dopant having a substantially uniform distribution in a direction parallel to the generally planar surface region.

27. A memory cell as in claim 25 wherein the control gate of each of the memory cells comprises a portion of a word line.

28. A memory cell as in claim 27 wherein the channel region comprises a dopant having a substantially uniform distribution in a direction parallel to the third surface region.

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